APPENDIX A

Mill Type:	Mg-based sulfite
Mill Code:	5
Information available:	NCASI 1991 MACT survey response (no information was provided for chemical recovery combustion equipment) Trip report

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Chemical recovery combustion equipment: 1 Copeland fluidized bed recovery reactor

Chemical recovery process/air pollution control equipment: MgO PM removal equipment + 3 venturi scrubbers

Chemical recovery process description: See Figure A-1. Weak red liquor from the 1st stage washer is concentrated in a 4-effect evaporator system to 45% solids. Evaporator overhead gases are vented directly to the atmosphere. Concentrated red liquor from the evaporators is sent to the recovery reactor. Magnesium oxide dust from the recovery reactor exit gases is collected and routed to the "mag system." The mag system consists of a washer and slaker, which are used to generate magnesium hydroxide ($Mg(OH)_2$). The $Mg(OH)_2$ is sent to one of three venturi scrubbers where it is used to scrub SO_2 from the inlet gas streams; occasionally the $Mg(OH)_2$ is sent directly to the acid plant. In addition to the recovery reactor exit gases after removal of MgO particulate, the following pulp mill sources are vented to the venturi scrubbers: (1) blow pit gases via the blow gas scrubber that uses fresh water as the scrubbing liquid, (2) high pressure accumulator gases, (3) acid plant fortification tower gases, (4) brown stock washer system vent gases, (5) vent gases from four storage tanks in the washing area, and (6) acid storage tank vent gases. Scrubbed gases from the venturi scrubbers are exhausted to the atmosphere through the main recovery stack. The magnesium bisulfite cooking acid formed in the venturi scrubbers is sent to the acid plant where make-up SO_2 from the sulfur burner is added to compensate for losses in the cooking and liquor processing.

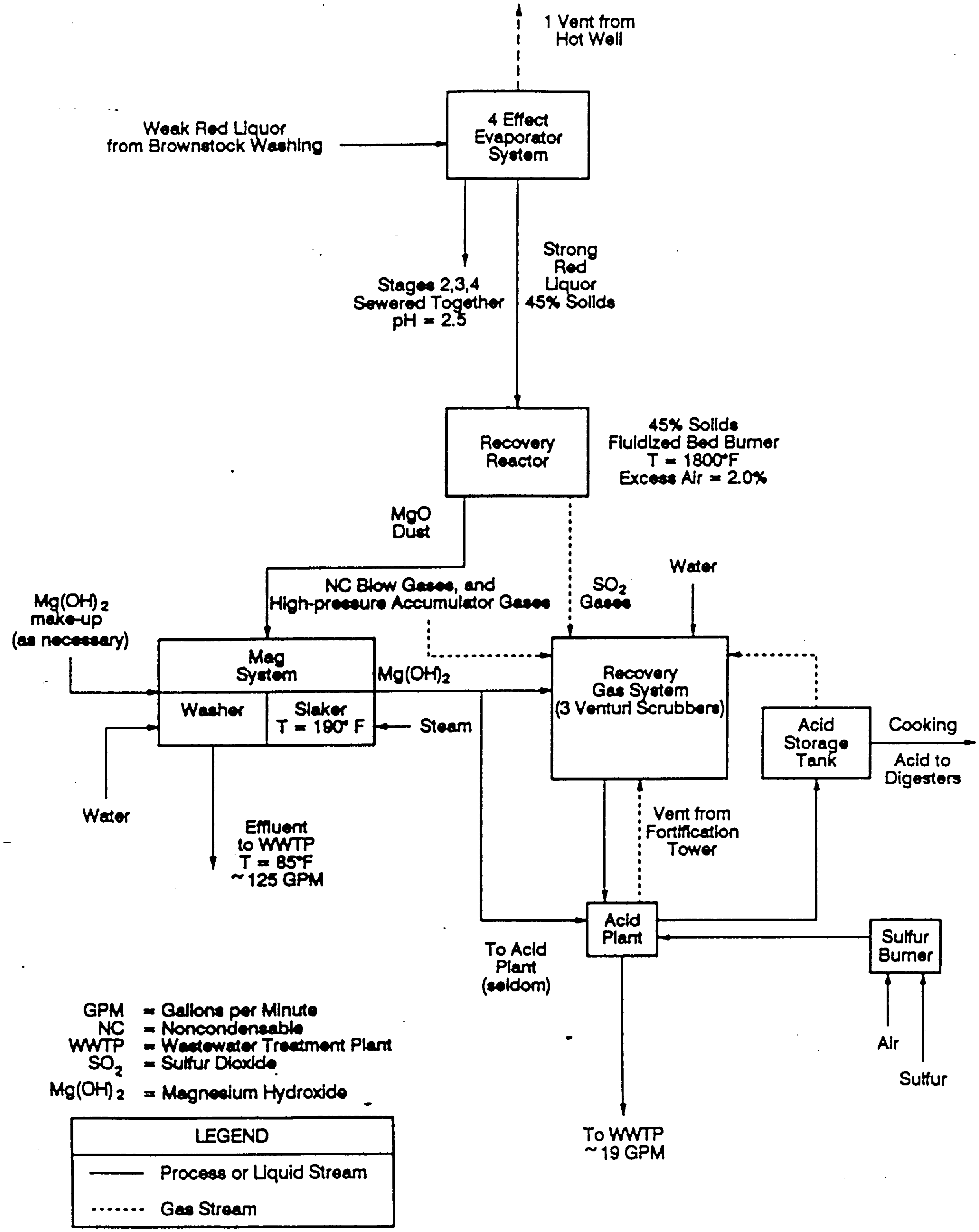


Figure A-1. Chemical recovery process at Mill 5.

Mill Type: Mg-based sulfite

Mill Code: 133

Information available: NCASI 1991 MACT survey response

Chemical recovery combustion equipment: 1 1974 B&W fluidized bed reactor

Chemical recovery process/air pollution control equipment: 1974 dust collector + cooling tower + 1974 3-stage packed (absorption) tower

Chemical recovery process description: See Figure A-2. Concentrated red liquor from the 3-effect evaporator set is sent to the fluidized bed reactor. Evaporator overhead gases are also routed to the fluidized bed reactor for incineration. Exit gases from the fluidized bed reactor are routed at a flow rate of approximately 80,000 acfm at 440°F through a waste heat boiler to produce process steam and then through 144-tube Research Cottrell dust collector where magnesium oxide (MgO) particulate is removed. Pulverized bed particle material is also collected using a MgO bed grinder dust collector. The collected MgO particulate (8,839 tons/yr) is sent to a slurry tank, ash thickener tank, ash filter, and slaker tanks to produce magnesium hydroxide ($Mg(OH)_2$). The $Mg(OH)_2$ slurry is the makeup scrubbing fluid in a 3-stage SO_2 absorption tower; a portion of the $Mg(OH)_2$ also is routed to the No. 3 evaporator. Exit gases from the dust collector are first routed to a gas cooling tower to improve SO_2 absorption and then to the 3-stage SO_2 absorption tower. The packing material in each stage of the absorption tower is 2 feet deep and the maximum liquid-to-gas ratio for each stage is 0.05 gal/acfm. The $Mg(OH)_2$ makeup rate for the 1st stage of the absorber is 191 gpm; the makeup rate for the 2nd and 3rd stages are 31 and 18 gpm, respectively. Purchased $Mg(OH)_2$ is also used in the absorber. The scrubbing fluid recirculation rate for the 1st stage of the absorption tower is 1,350 gpm; recirculation rates for the 2nd and 3rd stages are 1,575 and 2,350 gpm, respectively. The magnesium bisulfite solution formed in the absorption tower is sent to a fortification tower where makeup SO_2 from the sulfur burner is added. Exhaust gases from the fortification tower are routed to the absorption tower; there is also a vent from the tower to atmosphere. The flowrate of the gases entering the absorption tower is about 50,000 acfm at 140°F. Gases exit the absorption tower at approximately 130°F and are vented to the atmosphere.

Cost data: Capital and operating cost data for the dust collector and absorption tower are available in the NCASI 1991 MACT survey response.

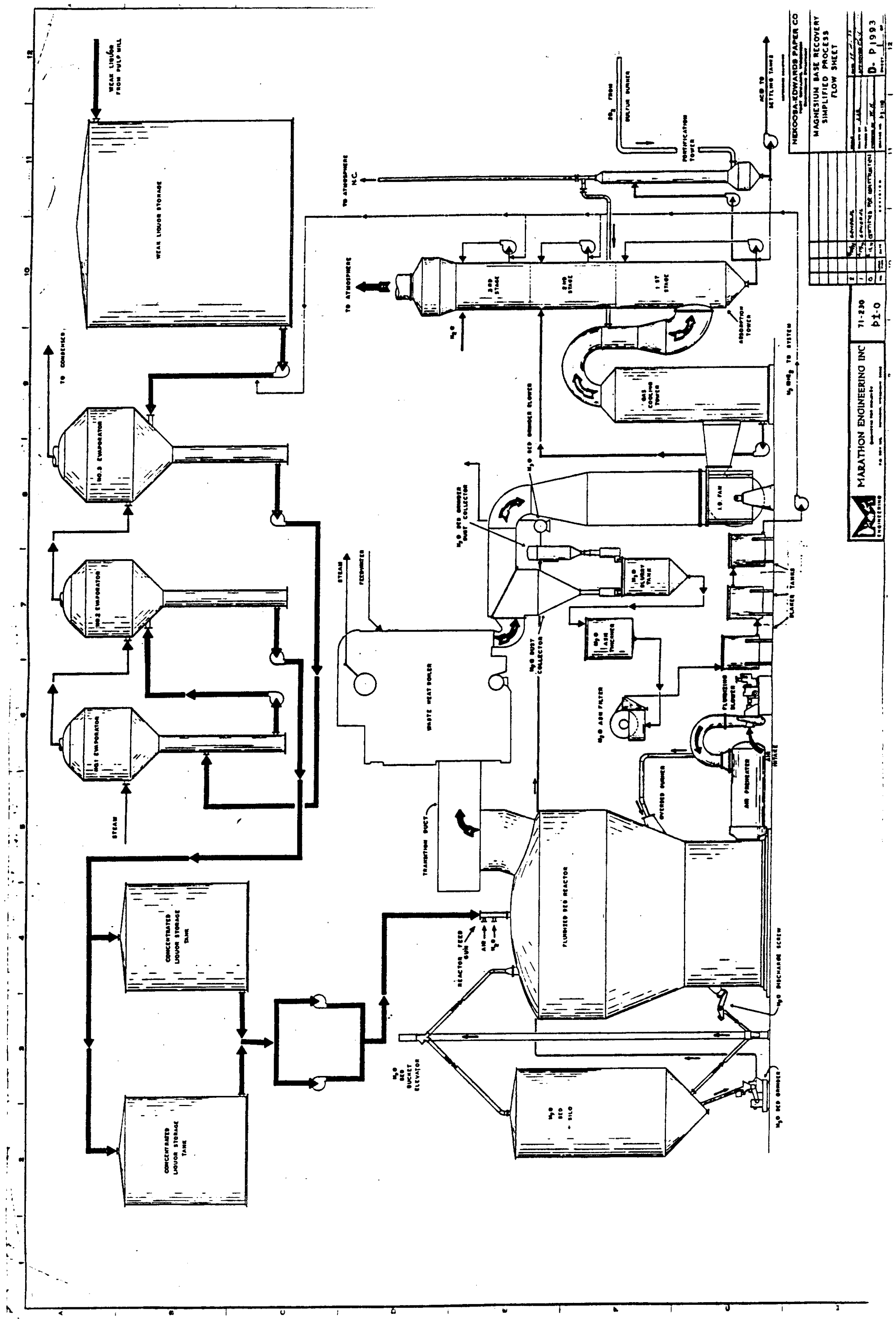


Figure A-2. Chemical recovery process at Mill 133.

Mill Type: Mg-based sulfite

Mill Code: 93

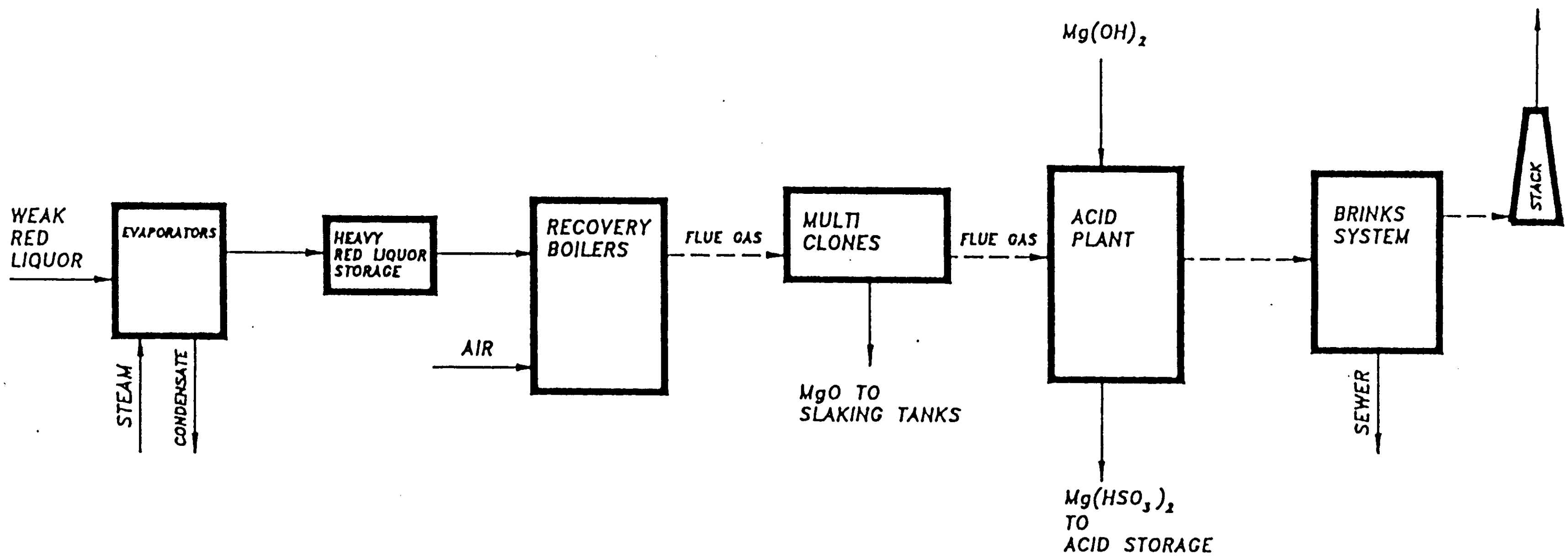
Information available: NCASI 1991 MACT survey response
Telephone contact

Chemical recovery combustion sources: 4 B&W recovery furnaces (installation dates--Nos. 1 and 2, 1954; No. 3 1957; and No. 4 1966)

Chemical recovery process/air pollution control equipment: 2 parallel sets consisting of multiclones + 1 cooling tower + 3-stage countercurrent packed absorption tower + Brinks demister system

Chemical recovery process description: See Figure A-3. Heavy red liquor from the evaporator sets is fired in one of four recovery furnaces. The red liquor solids firing rate per furnace ranges from approximately 454,000 to 480,000 lb/d. Combustion gases from recovery furnace Nos. 1 and 2 are combined and routed to one set of process/air pollution control equipment, and gases from recovery furnaces Nos. 3 and 4 are combined and routed to a second set of process/air pollution control equipment. Each set of process/air pollution control equipment consists of multiclones, a cooling tower, a 3-stage countercurrent packed absorption tower, and a Brinks demister system that consists of 3 canisters. This system provides for MgO particulate recovery (multiclones), SO_2 recovery (cooling and absorption towers) and PM emission control (Brinks demister system). Slaked MgO (i.e., $Mg(OH)_2$) is used as the scrubbing fluid in the SO_2 absorption tower. The magnesium bisulfite solution formed in the absorption tower is fortified with makeup SO_2 from the sulfur burner in a fortification tower, and the resulting product, $Mg(HSO_3)_2$, is sent to acid storage.

Cost data: Capital and annual costs for Brinks demister system included in NCASI 1991 MACT survey response.



PARTIAL PROCESS DIAGRAM

Figure A-3. Chemical recovery process at Mill 93.

Mill Type:	Mg-based sulfite
Mill Code:	80
Information Available:	NCASI 1991 MACT survey response Trip reports NCASI test report (Mill I)

Chemical recovery combustion equipment: 3 B&W recovery furnaces (installation dates--Nos. 1 and 2, 1957; No. 3, 1966)

Chemical recovery process/air pollution control equipment:
Recovery furnace No. 1--multiclones + cooling tower + 3 absorption towers + common educted venturi scrubber
Recovery furnace No. 2--multiclones + cooling tower + 3 absorption towers + common educted venturi scrubber
Recovery furnace No. 3--multiclones+ cyclone evaporator + 3-stage venturi scrubber + 1 absorption tower + common educted venturi scrubber

Chemical recovery process description: See Figure A-4. The solids content of the spent liquor is increased from approximately 25 percent to between 52 and 55 percent prior to firing in one of three recovery furnaces. The red liquor solids firing rate for recovery furnaces Nos. 1 and 2 is 562,400 lb/d/furnace; the firing rate for recovery furnace No. 3 is 588,000 lb/d. Exhaust gases from the furnaces contain MgO particulate and SO_2 gas. The MgO is recovered as a fine powder using multiclones. There are separate 4-chambered multiclones for each furnace. Following the multiclones, SO_2 is recovered in various absorption tower configurations. Exhaust gases from recovery furnace Nos. 1 and 2 are fed to separate cooling towers, then to separate SO_2 absorption towers. The exhaust stream from recovery furnace No. 3 is fed to a cyclone direct contact evaporator and then to a 3-stage venturi scrubber and absorption tower. From the SO_2 absorption towers, the exhaust streams from all three recovery furnaces are ducted to a common SO_2 scrubber and stack.

In collecting MgO, fresh water is sprayed from the sides of the hopper to wash the MgO particulate into a swirl chamber, forming an MgO slurry. The MgO slurry (magnesium hydroxide) is used as the scrubbing fluid in the venturi scrubbers and absorption towers. In addition, a portion of slurry is sewered at a rate of 50 gpm. Fresh water and evaporator condensate, if available, is used as makeup to the cooling towers and the recirculated water from the cooling towers is used as makeup water for the absorption towers. The No. 1 and No. 2 recovery furnace absorption towers are essentially the same except for the packing material. The No. 1 recovery furnace absorption towers use saddle packing, and the No. 2 recovery furnace absorption towers use ceramic tile packing. The No. 3 absorption tower also uses saddle packing. In addition to cooling tower water, magnesium hydroxide from the MgO processing area is also added as makeup scrubbing fluid in the absorption towers. Recovered liquid from the absorption towers is sent to the acid processing plant for fortification with SO_2 formed from combustion of elemental sulfur in a sulfur burner. The final SO_2 scrubber to which gases from all three recovery furnaces are routed is a 1985 AirPol educted venturi scrubber. The scrubbing medium is fresh water; sodium hydroxide is added if the inlet SO_2 concentration is greater than 100 ppm. During SO_2 excursions the pH of the recirculating liquid drops to a level of approximately 2 to 3; caustic is then added to increase the pH to a range of 7 to 9. The scrubber pressure drop is achieved with the use of pumps.

The SO_2 concentration in the exit gases from the recovery furnaces is about 10,000 ppm. The exit gases from the cooling towers contain about 7,000 ppm SO_2. The SO_2 concentration in the exit gases from the absorption towers is about 100 ppm, and stack gas SO_2 emissions range from approximately 90 to 140 ppm after the educted venturi scrubber.

Cost data: Capital and annual costs for the educted venturi scrubber are available in the NCASI 1991 MACT survey response.

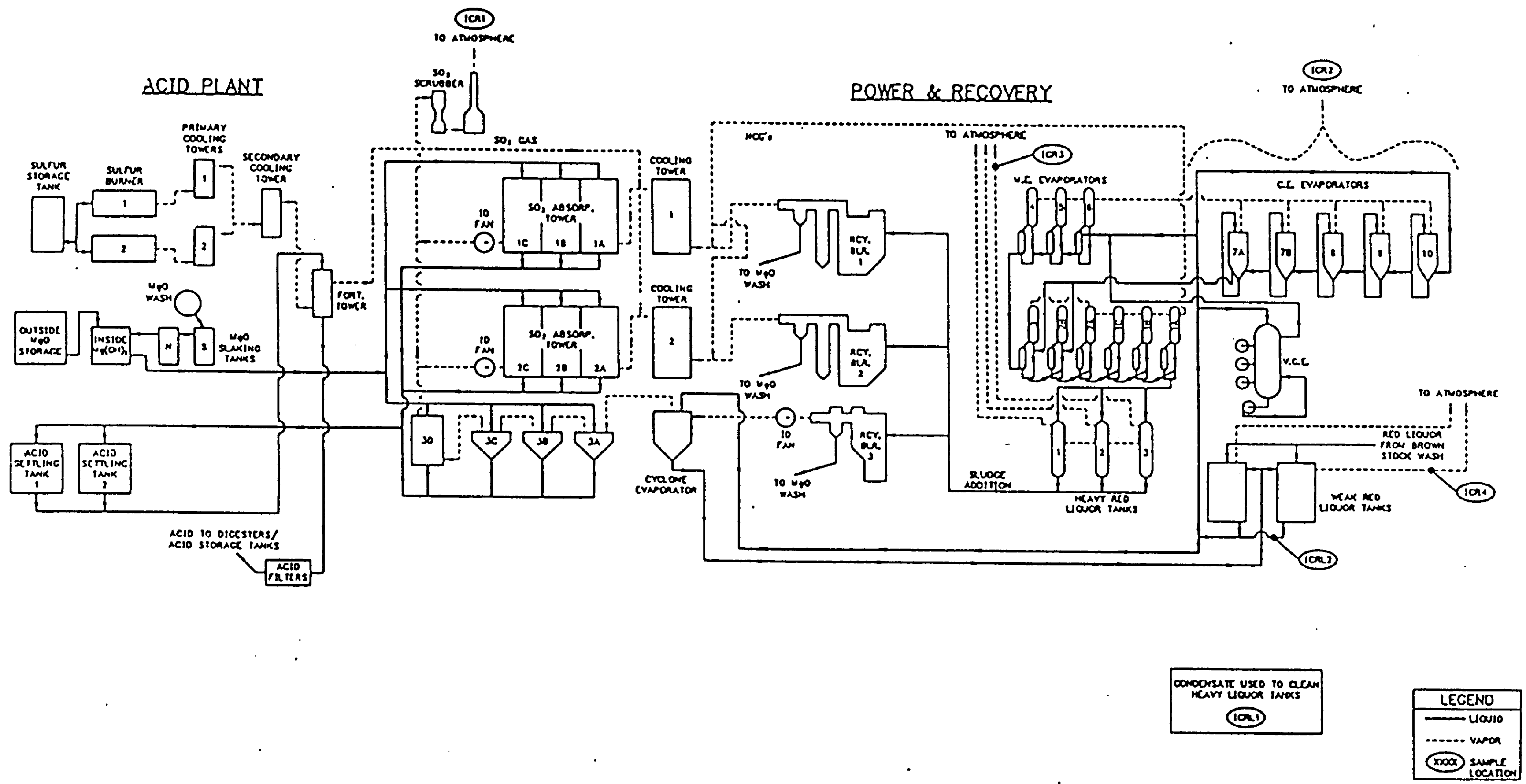


Figure A-4. Chemical recovery process at Mill 80.

Mill Type: Mg-based sulfite (+ kraft)

Mill Code: 12

Information Available: NCASI 1991 MACT survey response
Trip report

Chemical recovery combustion equipment: 1 1971 B&W recovery furnace

Chemical recovery process/air pollution control equipment: multiclone + 4-stage venturi scrubber + packed bed scrubber + mist eliminator.

Chemical recovery process description: See Figure A-5. Red liquor exits the multiple-effect evaporators (MEE) at a solids content of 55 to 60 percent and is fired in the recovery furnace at a design solids feed rate of 1.4 million lb/d. Noncondensible gases (~2,000 acfm) from the magnefite process digesters and MEE are routed to the recovery furnace for incineration. Recovery furnace flue gases consist primarily of SO_2 gas and MgO particulate. The flue gases first enter a multiclone where the MgO is recovered and then slaked to form $Mg(OH)_2$. Following the multiclone, SO_2 is recovered from the flue gas in a 4-stage venturi scrubber, which uses the liquid from the MgO slaking tanks as scrubbing fluid. Exit gases from the venturi scrubber pass through a packed bed scrubber and mist eliminator for additional control of air pollutants. The packed bed scrubber is a 1990 Advanced Air Technology scrubber. The design inlet flowrate is 160,000 acfm at 165°F. The scrubbing medium is a caustic solution that contains fresh water. The recirculation rate is 2,200 gpm; 50-percent concentration by weight caustic solution is added at a rate of about 1 to 3 gpm. The packing material is rigid Munters packing at a depth of 6 feet.

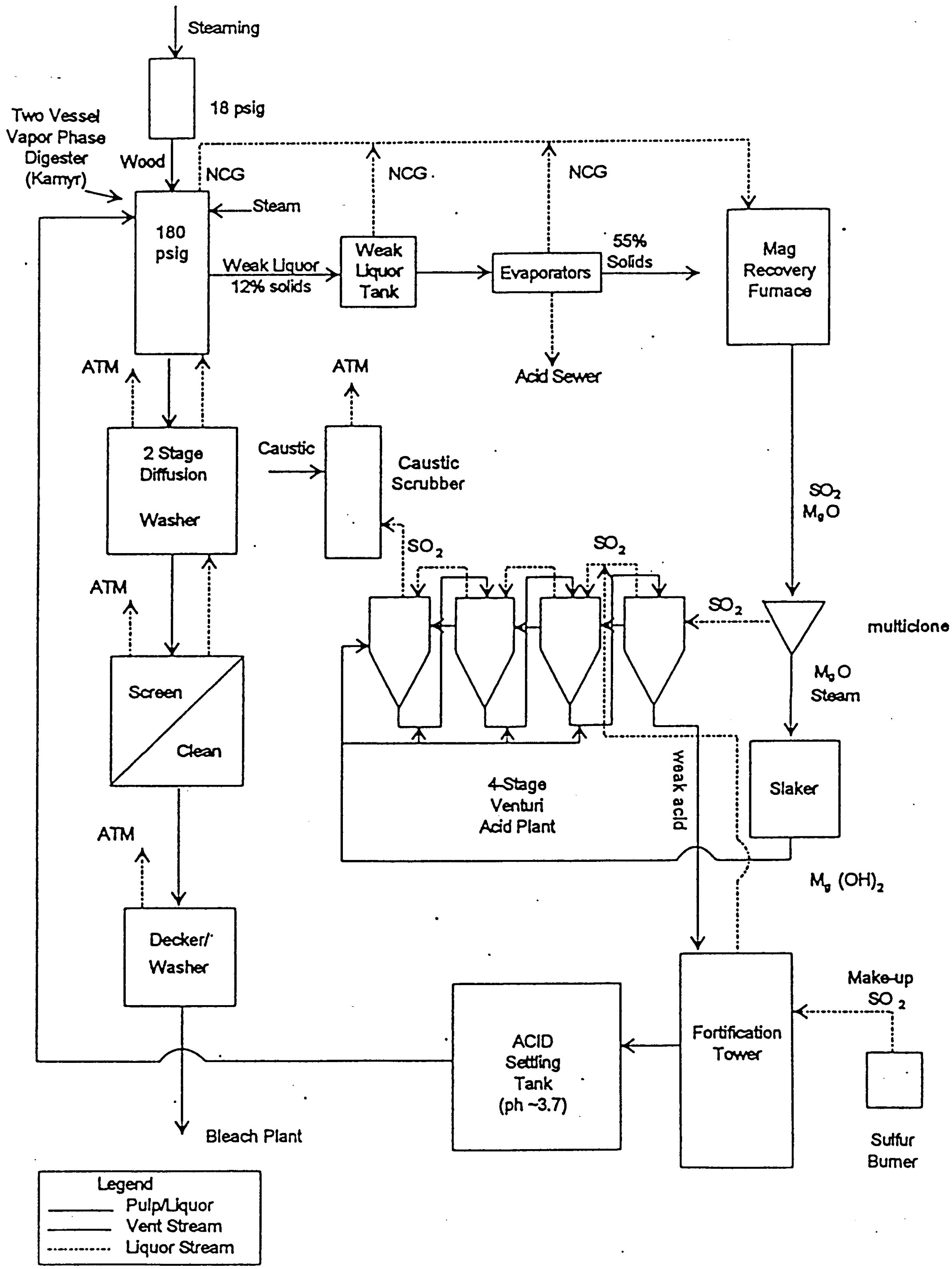


Figure A-5. Chemical recovery process at Mill 12.

Mill Type:	Mg-based sulfite (+ groundwood)
Mill Code:	A
Information Available:	1992 Lockwood-Post Directory Brief telephone contact

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Chemical recovery combustion equipment: 1 B&W recovery furnace (300,000 lbs steam/hr).

Chemical recovery process/air pollution control equipment: MgO recovery system. Information on additional equipment is not available.

APPENDIX B

Mill Type:	NH_3-based sulfite
Mill Code:	52
Information Available:	Mill-prepared process description NCASI 1991 MACT survey response (no information on recovery furnace was provided)

Chemical recovery combustion equipment: 1 B&W recovery furnace

Chemical recovery process/air pollution control equipment: cooling tower + absorption tower + Dynawave reverse jet scrubber + Brinks demister system

Chemical recovery process description: See Figure B-1. Concentrated spent liquor at 53% solids from the MEE is fired in a recovery furnace at a rate of 1.375 MM lb/d. Ash from the burning of the liquor is removed manually daily. Combustion gases, which contain SO_2, are routed to a cooling tower and then to an absorption tower to collect SO_2. The absorption tower is a 17-foot diameter packed bed tower that consists of two beds, one of which is 10 feet deep and the other 5 feet deep. Ammonium hydroxide is used in the tower to absorb SO_2, forming ammonium bisulfite. The ammonium bisulfite from the absorber is then fortified with SO_2 from a sulfur burner in a 4-foot diameter packed-bed fortification tower. In addition to recovery furnace flue gases, the following pulp mill sources are vented to the absorption tower: dump chests, washer feed chests, flushing liquor tanks, pressure washers, washer filtrate tanks, a filtered liquor tank, a liquor filter, acid storage tank, evaporator overhead gases, heavy liquor tanks, acid condensate tank, raw acid settling tank, weak liquor tank, contaminated hot well, condensate hot well, and fortification tower. Absorber exit gases are routed through a Dynawave reverse jet scrubber, which was installed in 1990 to control PM and SO_2 emissions. Makeup caustic (50 percent by weight) is added at a rate of 0 to 3 gpm to maintain a pH of 6.0. The SO_2 removal efficiency is approximately 80%. Final control of PM emissions is provided by a Brinks mist eliminator system. This system consists of 95 cylindrical filter elements (also called candles) in 6 tanks. Each candle is approximately 10-feet long with an outside diameter of 2 feet. Major modifications to the tank configurations where made in 1985 to improve washing efficiency and gas circulation through the candles. The modifications plus installation of the Dynawave scrubber improved the operation of the demister system by reducing plugging of the candles.

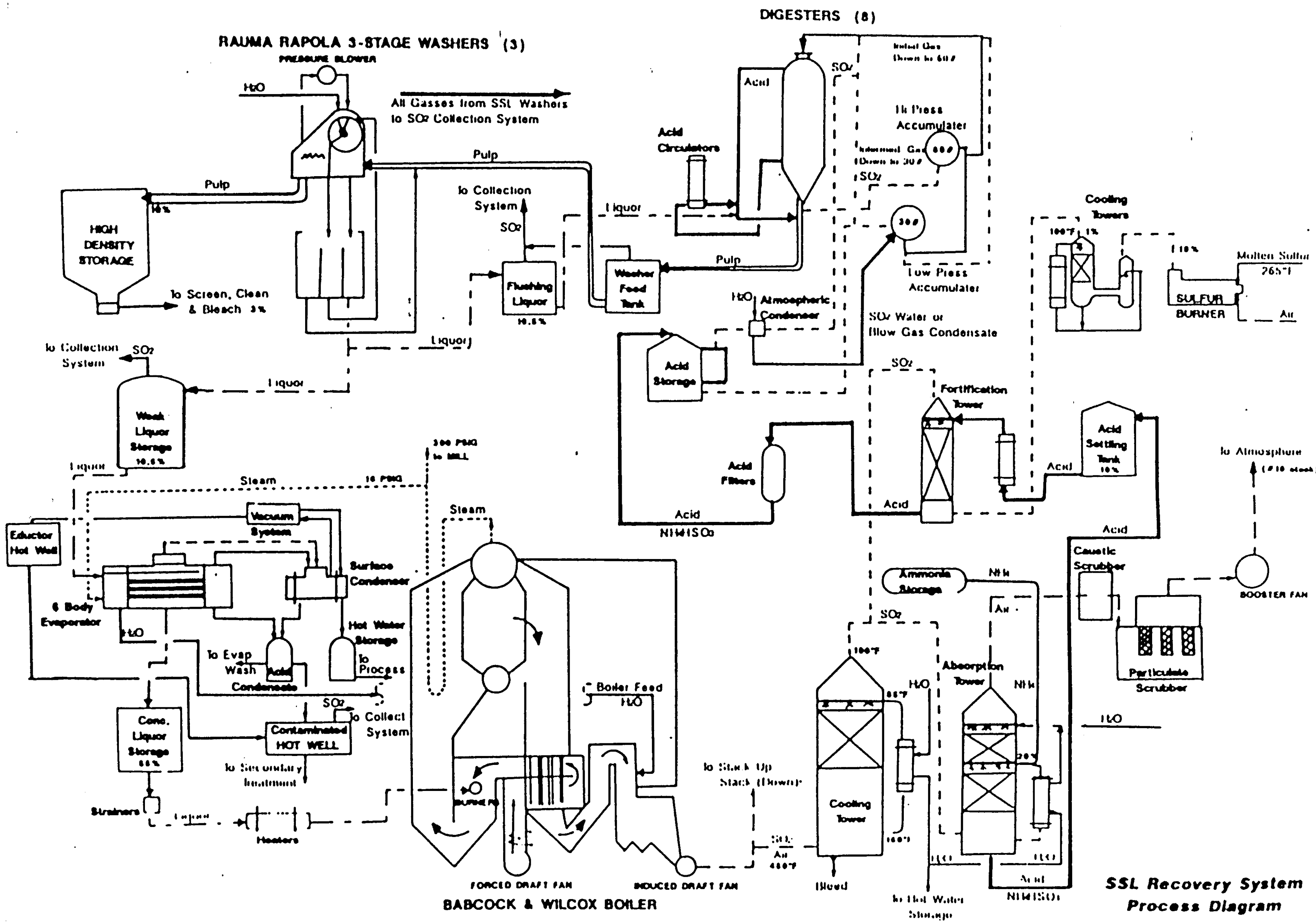

Figure B-1. Chemical recovery process at Mill 52.

Mill Type:	NH_3-based sulfite
Mill Code:	94
Information Available:	NCASI 1991 MACT survey response Trip report

Chemical recovery combustion equipment: 1 1974 C-E recovery furnace (performance specs included with NCASI 1991 MACT survey response)

Chemical recovery process/air pollution control equipment: absorber-cooler tower + mesh pad demister + Brinks demister system

Chemical recovery process description: See Figures B-2 and B-3. Red liquor is concentrated to between 50 and 55 percent solids in vapor recompression (VRC) and multiple effect evaporators (MEE). Concentrated red liquor is then fired at a rate of 1.38 MM lb red liquor solids/d in a 1974 C-E recovery furnace to recover SO_2 and generate steam. The process does not require smelt dissolving tanks; ash produced during combustion is periodically removed from the furnace bottom. Combustion gases are routed to an absorber-cooler, where the gases are first cooled in the lower two zones to increase SO_2 recovery and then SO_2 is absorbed by aqueous ammonia in the upper two zones. The VRC evaporator, MEE condenser, and miscellaneous tanks are vented to the absorber-cooler. The ammonium bisulfite solution from the absorber-cooler is routed to the acid plant, where it is fortified with makeup SO_2 from a sulfur burner. The absorber-cooler also provides some PM emission control. Absorber-cooler exit gases are routed through a mesh pad located at the top of the absorber-cooler tower and a Brinks demister system to collect absorber-generated ammonia salts and recovery furnace PM. The Brinks demister system consists of 6 tanks with 21 fiberglass and polyester candles in each tank. The candle elements are 10 feet long with a diameter of 18 inches.

Limerock towers are used to collect SO_2 emissions from miscellaneous tank vents, acid plant overgases, and the blow tank recovery system.

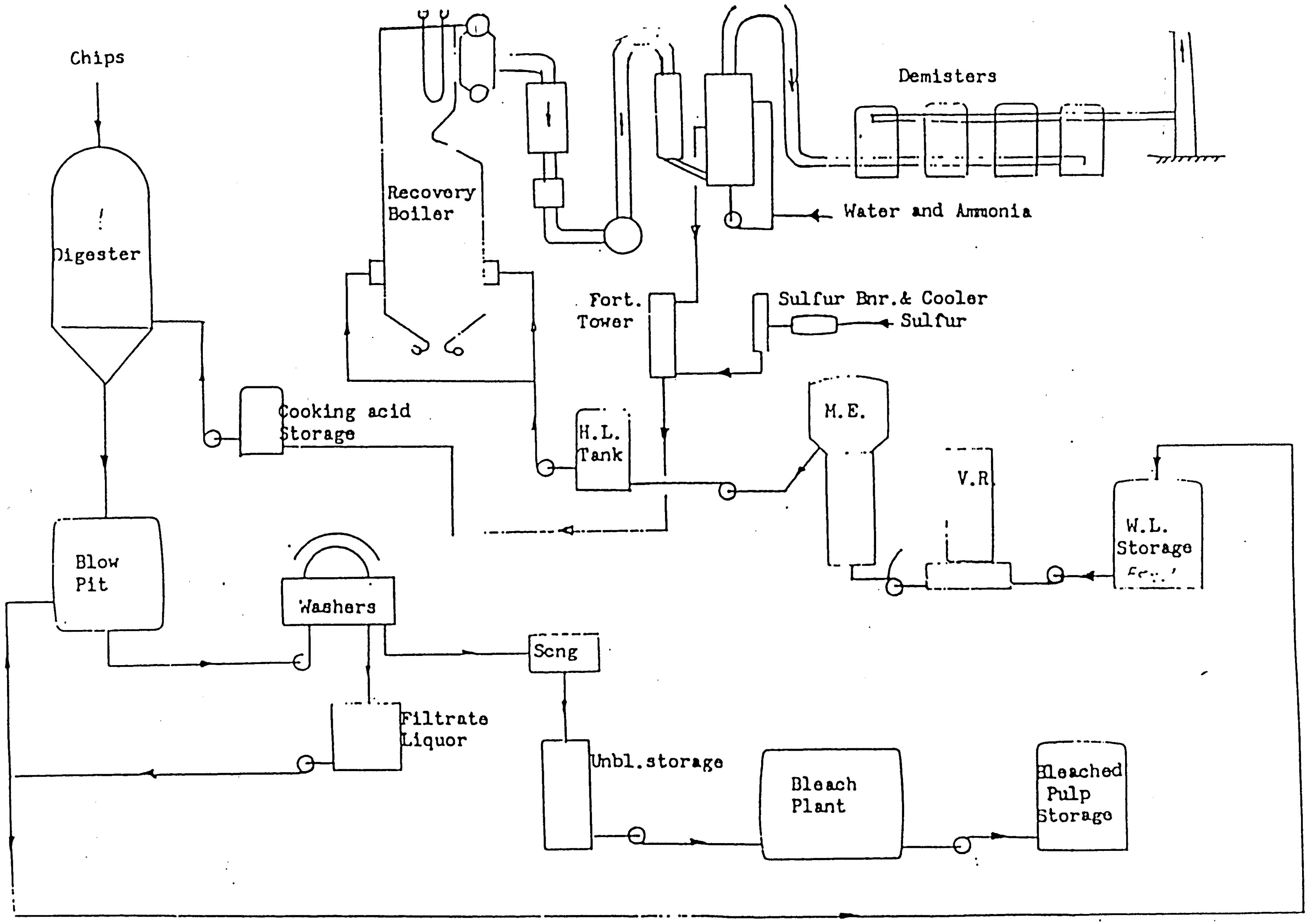

Figure B-2. Chemical recovery process at Mill 94.

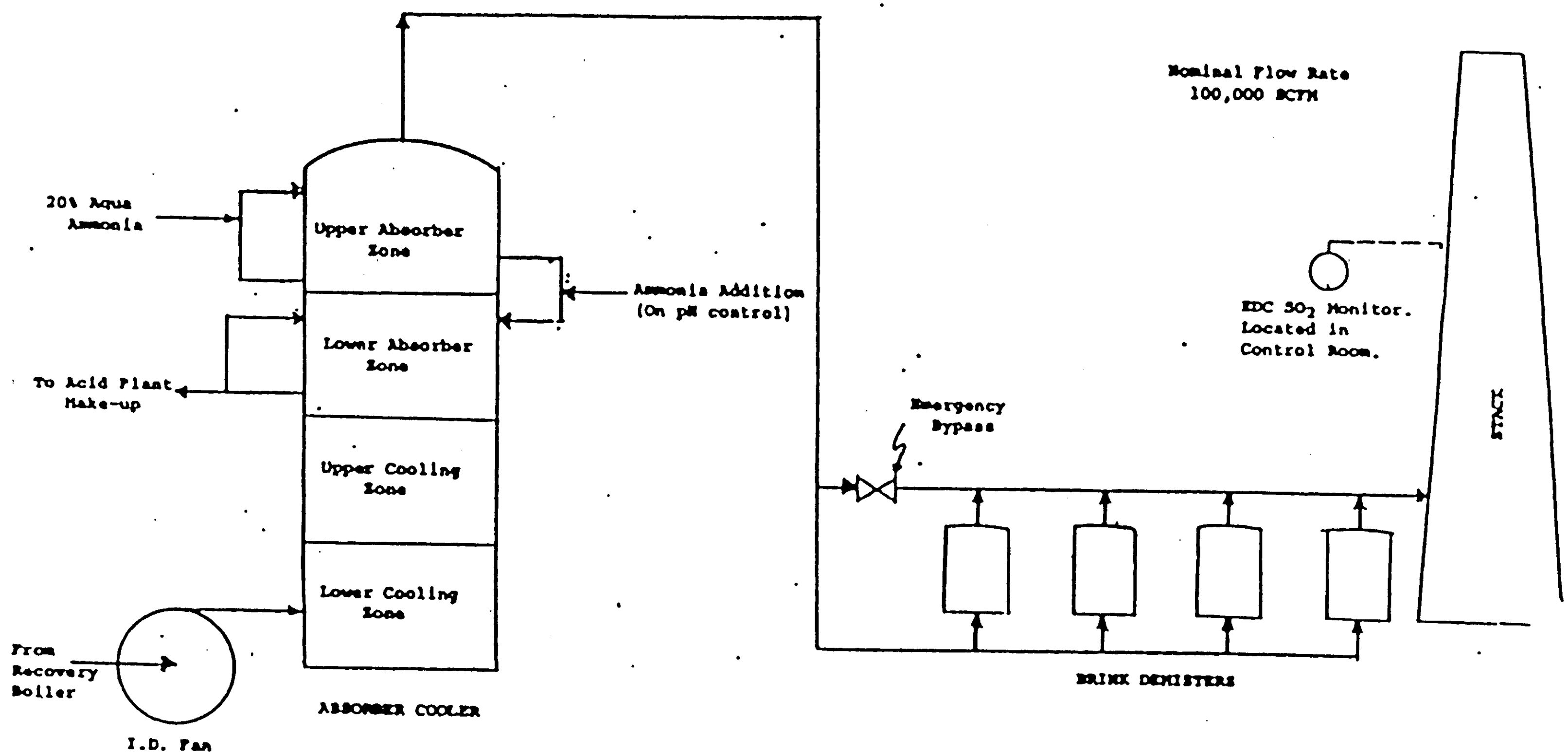

Figure B-3. Mill 94 recovery furnace air pollution controls.

Mill Type: NH_3-based sulfite

Mill Code: 128

Information Available: NCASI 1991 MACT survey response
NCASI test report (Mill P)

Chemical recovery combustion equipment: 1 1975 B&W recovery furnace

Chemical recovery process/air pollution control equipment: Absorption/cooling tower + Brinks demister system

Chemical recovery process description: See Figure B-4. Spent sulfite liquor is concentrated in two parallel sets of falling film 6-effect MEE's to 54 percent solids. The concentrated liquor is fired in a 1975 B&W recovery furnace at an average solids firing rate of 1.3 MM lb/d. The recovery furnace produces heat for steam generation and oxidizes sulfur compounds to SO_2. A five section absorption tower is used to recover SO_2 as bisulfite and capture additional heat. In the first section, flue gases at 450°F are quenched with a clean water spray to 160°F. In the next two sections, which are heat recovery zones, the flue gases are cooled to about 120°F. Most of the recovered heat drives the vacuum evaporator. Evaporator NCG's enter the tower in the heat recovery zone. The final two sections are SO_2 recovery zones where ammonia is used to absorb SO_2 as ammonium bisulfite. Ammonium bisulfite from the absorption tower is transferred to an ammonia tower, where additional ammonia, chilled water, and SO_2 are added. The solution is then transferred to a pressure absorption (fortification) tower where makeup SO_2 from the sulfur burners is added. Exit gases from the recovery furnace absorption tower are routed to a Brinks demister for removal of particulate ammonium salts.

"Nuisance gases" from pulping and acid production are routed to a wet scrubber that uses a make-up solution of either soda ash or caustic. Off gases from acid storage tanks and digester low pressure relief system are vented to the fortification tower.

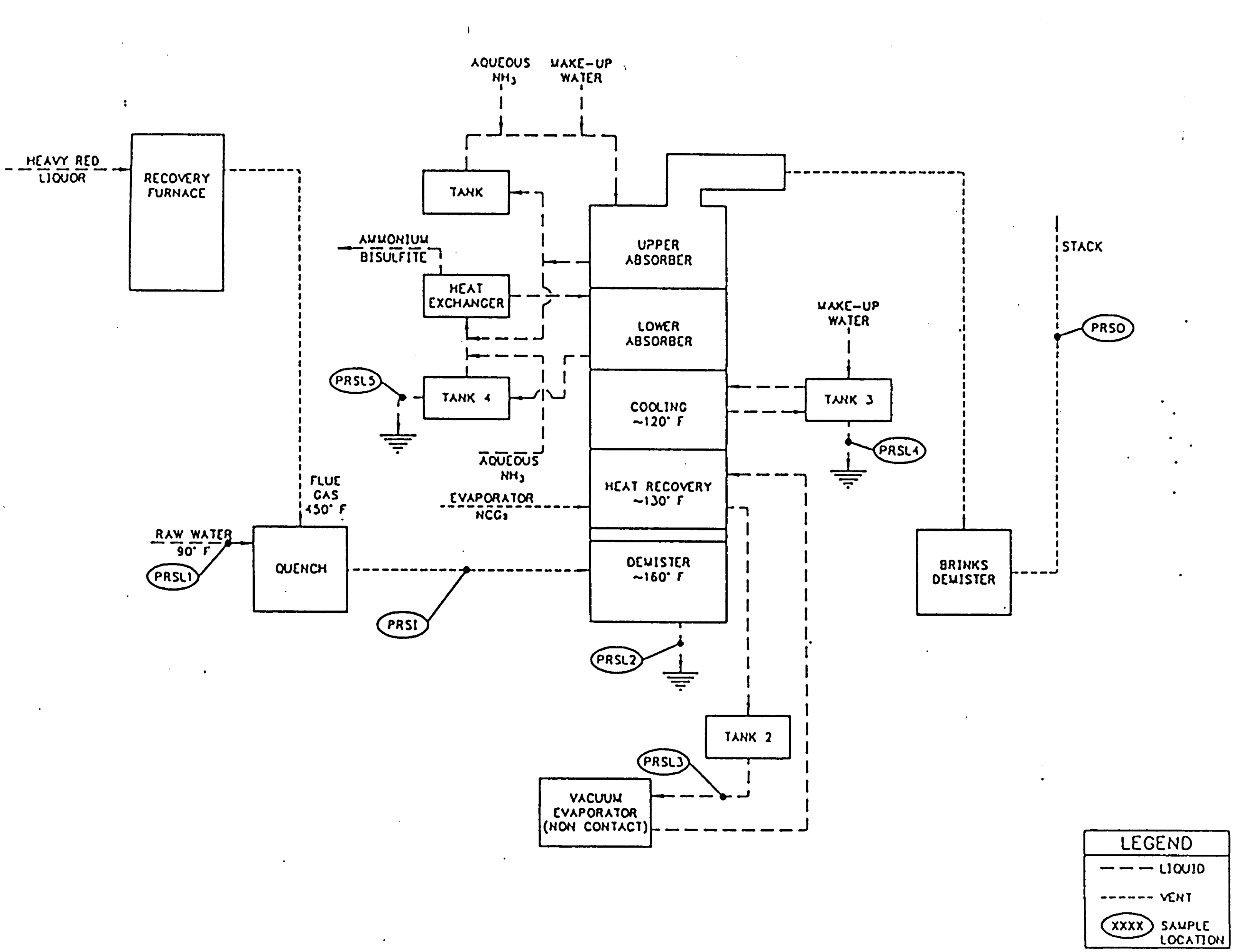

Figure B-4. Chemical recovery process at Mill 128.

Mill Type:	NH_3-based sulfite
Mill Code:	121
Information available:	NCASI 1991 MACT survey response Telecon

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Chemical recovery combustion equipment: 2 recovery furnaces (1968 C-E and 1969 B&W)

Chemical recovery process/air pollution control equipment: SO_2 absorption tower + mesh pads + fume filters.

Chemical recovery process description: See Figure B-5. Spent liquor at 15% solids is concentrated to 50% solids in a Rosenblatt falling film evaporator. Concentrated liquor is fired into one of two recovery furnaces. Recovery furnace No. 2 is a 1968 C-E furnace and recovery furnace No. 4 is a 1969 B&W furnace. Combustion gases from the recovery furnaces are combined and then cooled with water and scrubbed with an aqueous ammonia solution in an SO_2 absorption tower. The water used in the absorption tower is fresh mill water. The absorption tower is a 1977 bubblecaps, tray tower manufactured by R. Katzen Associates. In the absorption tower, SO_2 reacts with the ammonium hydroxide solution to form an ammonium bisulfite solution. The ammonium bisulfite solution is returned to the sulfite pulping process. Gases exiting the SO_2 absorber pass through mesh pads and four fume filters to remove carryover liquid and PM prior to discharging to the atmosphere. These devices were also installed in 1977. The mesh pad, which is located at the top of the SO_2 absorption, was manufactured by Rust Engineering. The fume filters are Monsanto Brinks-type filters. These filters consist of four tanks containing 21 packed polyester candle elements each. One candle element is 10 feet high with a 2-foot diameter.

Emissions from pulp mill sources, such as the evaporator, are controlled with a separate SO_2 scrubber (referred to as the "pulp mill SO_2 scrubber"); pulp mill sources are not integrated with the chemical recovery sources.

Cost data: Capital and annual costs for SO_2 scrubber and PM fume filters available in NCASI 1991 MACT survey. response.

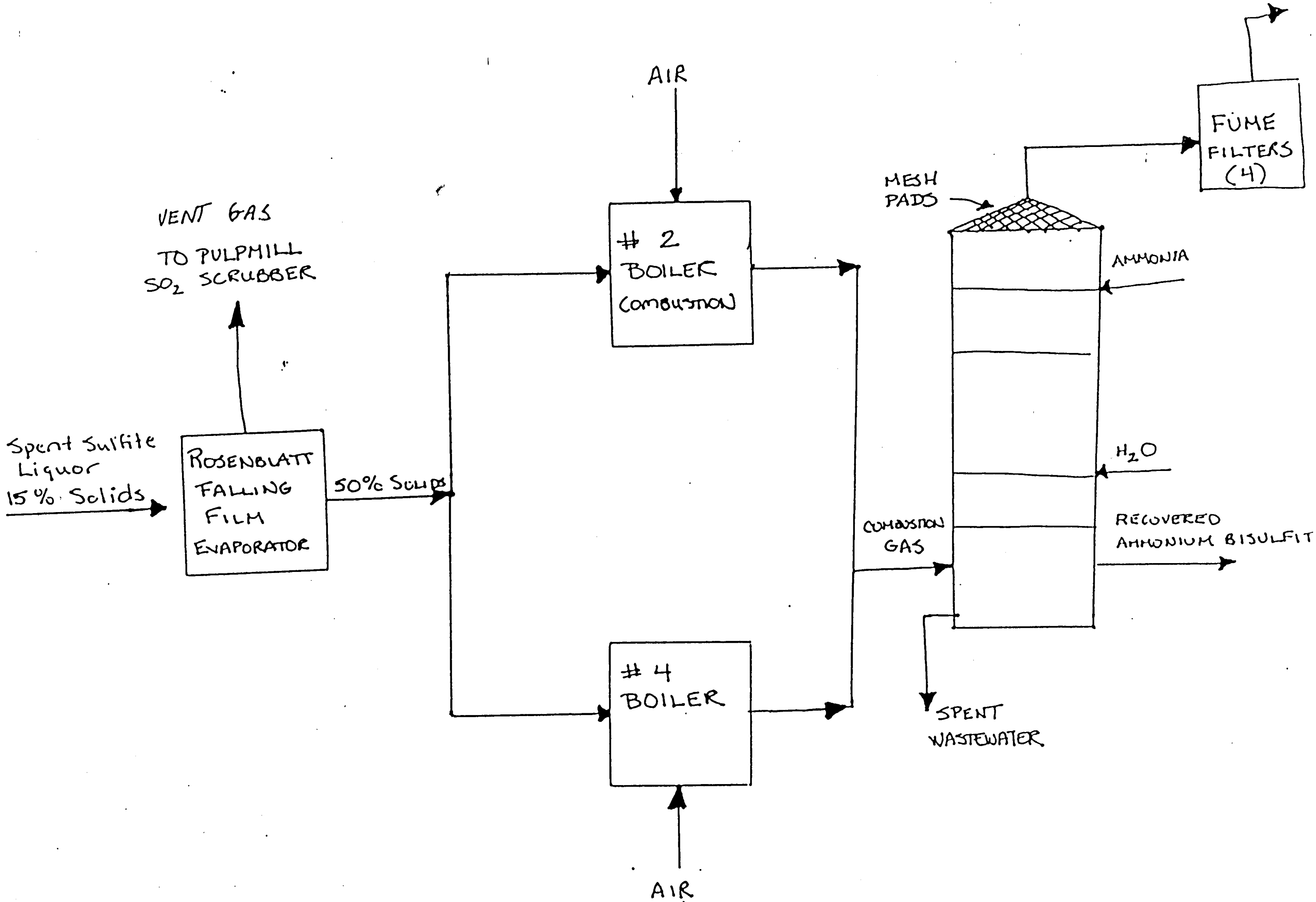

Figure B-5. Chemical recovery process at Mill 121.

Mill Type: NH_3-based sulfite

Mill Code: 41

Information Available: NCASI 1991 MACT survey response (incomplete information was provided)

Chemical recovery combustion equipment: 4 recovery furnaces (Nos. 8 and 10 are 1977 and 1987 Loddby furnaces; Nos. 6 and 7 were installed in 1974, information on the manufacturer is not available.)

Chemical recovery process/air pollution control equipment: SO_2 scrubber/absorber + Brinks demister system (possibly 2 parallel sets, although unclear from survey response.)

Chemical recovery process description: See Figure B-6. Spent liquor at 60% solids from the evaporators is fired in one of four recovery furnaces. Recovery furnaces Nos. 8 and 10 are Loddby furnaces with liquor solids feed rates of 750,000 lb/day each. Information on the firing rate or manufacturer for recovery furnaces Nos. 6 and 7 are not available. Combustion gases are routed to an SO_2 scrubber/absorber where SO_2 in the gases is absorbed using an ammonium solution. It is unclear from the survey response whether combustion gases from all 4 recovery furnaces are combined and routed to one scrubber/absorber or if there are two or more scrubber/absorbers. The resulting acid is then enriched with SO_2 in a fortification tower. Evaporator overhead gases are routed to the fortification tower, and the fortification tower is vented to the SO_2 scrubber. Exit gases from the SO_2 scrubber pass through fiber bed filters prior to discharge to the atmosphere. The fiber bed filters were manufactured by Monsanto. The fiber bed filter systems for the recovery furnaces Nos. 6 and 7 contain 40 elements each, and the fiber bed filter for recovery furnace No. 8 contains 81 elements. Information on the fiber bed filter system for the recovery furnace No. 10 is not available. Again, the number of separate demister systems is unclear based on survey response data. The elements are 12 feet long and 2 feet in diameter. The mill plans to replace the filter media with a denser media.

Cost data: Annual cost data are available for the Brinks demister system are available in the NCASI 1991 MACT survey response.

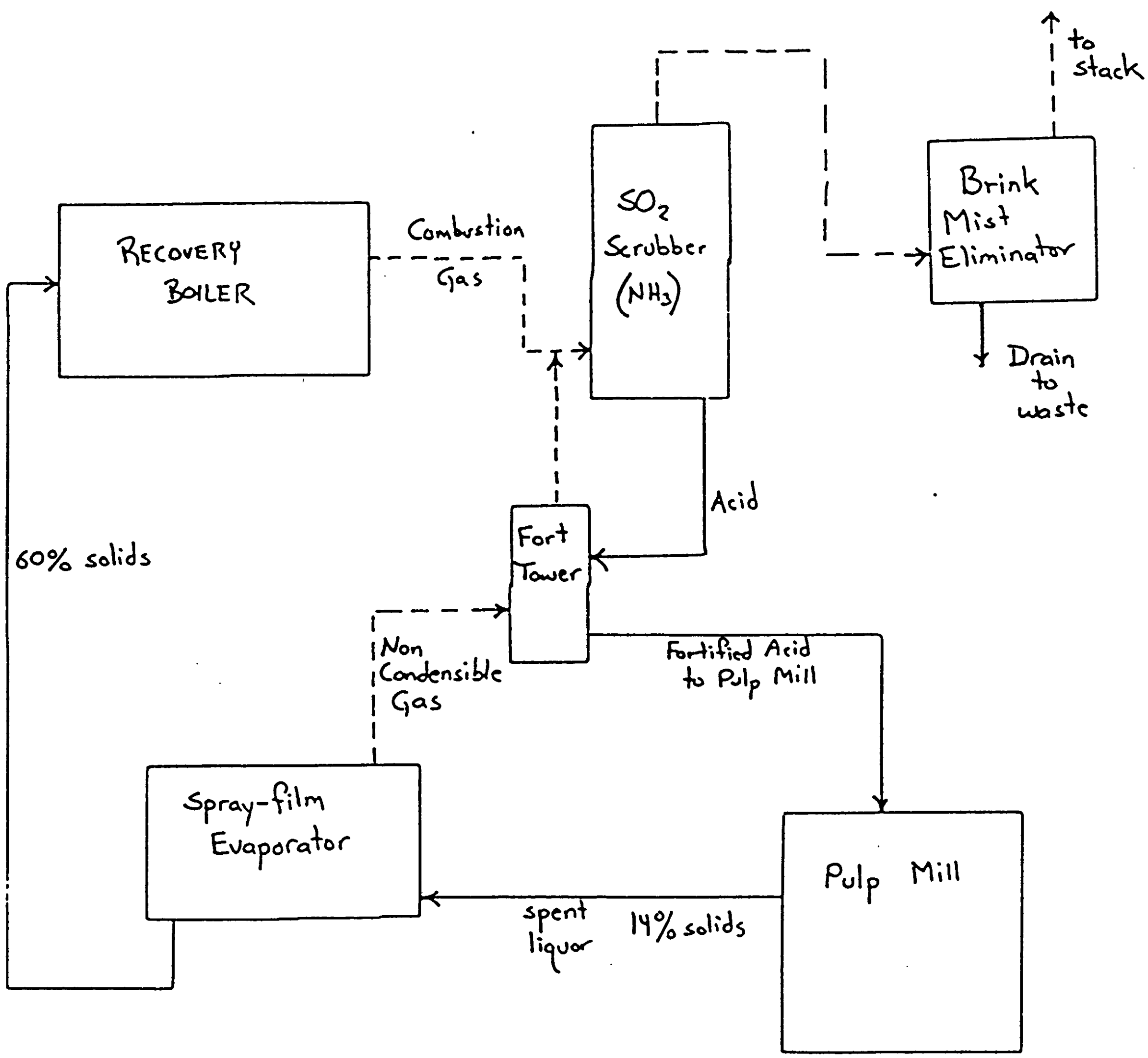

Figure B-6. Chemical recovery process at Mill 41.

Mill Type: NH_3-based sulfite

Mill Code: B

Information Available: Brief mill contact

Chemical recovery combustion equipment: Marathon Engineering combustion unit (one-of-a-kind)

Chemical recovery process/air pollution control equipment: venturi scrubbers (direct contact evaporators) + absorption tower (bubble trays) that includes a heat recovery stage. Additional information from the mill is needed.

Chemical recovery process description: Insufficient information available to describe process.